NASA TECHNICAL MEMORANDUM

NASA TM X-71837

NASA TM X-71837

A PRELIMINARY REPORT OF MULTISPECTRAL SCANNER DATA FROM THE CLEVELAND HARBOR STUDY

by Don Shook, Charles Raquet, Roger Svehla, Douglas Wachter,
Jack Salzman, Tom Coney, and Dick Gedney
Lewis Research Center
Cleveland, Ohio 44135

November, 1975

(NASA-TM-X-71837) A PRELIMINARY REPORT OF MULTISPECTRAL SCANNER DATA FROM THE CLEVELAND HARBOR STUDY (NASA) 40 p HC $4.00 CSCL 13E
N76-13638
Unclas
G3/45 05639

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A PRELIMINARY REPORT OF MULTISPECTRAL SCANNER DATA FROM THE CLEVELAND HARBOR STUDY		5. Report Date 6. Performing Organization Code
7. Author(s) Don Shook, Charles Raquet, Roger Svehla, Douglas Wachter, Jack Salzman, Tom Coney, and Dick Gedney		8. Performing Organization Report No. E-8550
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		10. Work Unit No. 11. Contract or Grant No. 13. Type of Report and Period Covered Technical Memorandun
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A report on the remote sensing part of an E. P. A. study of the water quality in the Cleveland harbor area is presented. The study was performed for E. P. A. by the Ohio State University Center for Lake Erie Research, Case Western Reserve University, and the NASA Lewis Research Center. Imagery obtained from an airborne multispectral scanner is presented. A synoptic view of the entire study area is shown for a number of time periods and for a number of spectral bands. Using several bands, sediment distributions, thermal plumes, and Rhodamine B dye distributions are shown.

17. Key Words (Suggested by Author(s))	18. Distribution Statement Unclassified - unlimited STAR Category		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price*

* For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-C-168 (Rev. 10-75)

A PRELIMINARY REPORT OF MULTISPECTRAL SCANNER

DATA FROM THE CLEVELAND HARBOR STUDY

by Don Shook, Charles Raquet, Roger Svehla, Douglas Wachter,
Jack Salzman, Tom Coney, and Dick Gedney

Lewis Research Center

E-8550

SUMMARY

A report on the remote sensing part of an E.P.A. study of the water quality in the Cleveland harbor area is presented. The study was performed for E.P.A. by the Ohio State University Center for Lake Erie Research, Case Western Reserve University and the NASA Lewis Research Center. Imagery obtained from an airborne multispectral scanner is presented. A synoptic view of the entire study area is shown for a number of time periods and for a number of spectral bands. Using several bands, sediment distributions, thermal plumes, and Rhodamine B dye distributions are shown.

INTRODUCTION

The Cleveland Harbor Study took place in the time period July 17 to July 29, 1975. The participants in this E.P.A. sponsored study were Case Western Reserve University, Ohio State University, and NASA Lewis Research Center. The objective of the study was the verification of E.P.A. models of flow and mixing of river pollutants in lake waters. To achieve this objective, in situ measurements were made of water quality, temperature, and flow patterns by both O.S.U. and C.W.R.U. personnel.

At the request of the E.P.A., multispectral imagery of the study area was taken by Lewis personnel while the in-the-water measurements were being made. This data was taken using the NASA C-47 aircraft. Imagery from the multispectral data was made available to O.S.U. and C.W.R.U. personnel within approximately 2 to 6 hours after completion of the flights. This imagery was used for planning the next set of measurements.

The study area was laid out on a grid, and sampling stations were chosen prior to the study. Measurements were made at these stations daily by O.S.U. personnel using the 60-foot research vessel Hydra. To aid in the river-flow pattern measurements, Rhodamine B dye was dumped into the water from the C.W.R.U. boat on three separate days during the study period.

SCANNER FLIGHTS AND SHIP OPERATIONS

A summary of activities during the study is shown in table I. As seen in the table, as many as twenty-seven flight lines were flown in one day. The days of maximum activity were July 25, 28, and 29. Three scanner flights were made prior to any O.S.U. ship operation. The first of these was a test flight, and the second and third flights were made to provide imagery to aid in choosing sampling sites. Sixteen sampling sites were used. These sites were in the vicinity of the river mouth and the breakwall. The actual locations are shown in figure 1. The time lines in the figure indicate the direction of the flight lines for the time of day flown. Table II shows in detail the flight lines that were flown during the study. The table contains all information on the flights such as time, direction, altitude, some notes on the weather, and camera information.

SCANNER IMAGERY

The scanner flown was a Bendix Modular Multispectral Scanner (M^2S). Eleven channels of digital data were recorded simultaneously on tape. The central wavelength and bandwidth for each scanner band are the following:

Band number	Central wavelength nanometers	Bandwidth nanometers
1	410	60
2	465	50
3	515	40
4	560	40
5	600	40
6	640	40
7	680	40
8	720	40
9	810	100
10	1 015	90
11	11 500	1000

Images to be presented were obtained from the scanner high-density digital tape using a digital to analog converter and an EDO Western Model 572A fiber optics recorder using 3M type 7869 Dry Silver film. The EDO Western operator adjusted the gains and bias to give brightest areas (white) where the water reflectance was indicated to be the highest and the dark areas (black) where the water reflectance was lowest. This provided the greatest possible number of gray scales for areas of intermediate water reflectance. Since this was independently done for each band, it is not possible to accurately compare the brightness of different bands with each other.

The scanner imagery has been divided into three categories to show three properties of major interest to the E.P.A. of the water in the Cleveland harbor area during the study. These three properties are obtained directly from the scanner imagery without recourse to a detailed computer-aided analysis of the data. The first property to be discussed is total suspended solids. A synoptic view of the sediment distribution will be shown. Secondly the initial Rhodamine B dye distribution and degree of mixing with the sediment plume will be shown. Thirdly the surface temperature in the harbor area will be presented.

Sediment Plume

Figure 2 shows the harbor area on July 25 between 10:00 and 10:30 using band 4. The image is a mosaic of three flight lines made at 5000 feet. The flight line over the river mouth was made at 10:00 just before the Rhodamine B dye was dumped there. Referring to the sampling sites in figure 1, the figure 2 data indicates that relative to sites 10, 11, and 12, the total suspended solids at sites 1, 3, and 16 should be high. Sites 2, 4, 15, and 13 lie close to the plume edge so that their exact location and the sampling time is important. Sites 6, 7, and 8 should have an intermediate suspended solid concentration.

Figure 3 shows the harbor area also on July 25 but at 3:41 and 4:32 p.m. using band 6. The data show that the sediment plume has changed substantially from what it was in figure 2. The direction of the plume is affected by wind direction and lake currents. This imagery indicates that sites 13, 15, 16, and possibly 3 will show relatively less sediment in this distribution than the one at 10:00. The bright area in the image to the right of the harbor entrance and outside the breakwall could be the remnant of the morning plume. Figures 2 and 3 were made with different scanner bands. However, as shown in reference 1, bands in the green-to-red wavelength range show sediment plumes more or less equally well.

Figures 4 to 7 show the sediment distributions on the remaining days of the study. The images show the day to day variations in the sediment distribution. In figure 5(a) band 4 (green) and band 7 (red) image of the 10:02 flight data is shown. The bright area along the edge of the band 4 image is due to air scattering. The overall variation of the reflectance is similar for the two bands but with band 4 perhaps showing a greater difference in the water east of the river mouth compared to that west of the river mouth inside the breakwall. Figures 8 to 18 also show the sediment plume during the study. However, these will be discussed in terms of the dye distribution.

Dye Distribution

Rhodamine B dye was dumped in the river near the mouth on the morn-

ing of July 25. The dye was easily visible from the air during the morning flight and traces along the breakwall could be seen in the afternoon. Figure 8 shows three images made from data taken at 10:15, 10:27, and 10:38. In the 10:15 band 4 image, the dye is just visible as a small dark spot at the river mouth. In the 10:27 band 5 image, the dye appears as a bright spot at the river mouth and in the 10:38 band 4 image a dark spot. In figure 9 the 10:50 flight line using bands 4 and 5 shows the dye to have dispersed some and moved to the center of the breakwall area.

The reason the area of water containing the concentrated dye appears as a dark spot in the band 4 image and a bright spot in the band 5 image is the following: The peak of the dye fluorescence emission is in band 4 (ref. 2) but the absorption is also the highest. There is always a positive contribution by the dye fluorescence to the radiance even with extreme self-absorption. However, the net radiance in the dye area is much lower because the dye is absorbing the light that would have been reflected by the sediment and water. In band 5 the dye absorptance is less for the same concentration and the net radiance is higher than the surrounding water. Band 6 lies further in the wings of the dye fluorescence wavelength region and the concentrated dye area appears bright on the image. The dye was not detectable on the band 7 images. The variation of reflectance with dye concentration is, of course, very nonlinear.

Figure 10 shows images made from bands 4 and 8 from the 3:35 p.m. flight on July 25. A comparison of these images indicates that the dye has completely dispersed into the sediment distribution which is seen to be essentially the same for band 8 with no dye fluorescence contribution and band 4. Some difference in these images is apparent along the shore line.

On July 28 dye was dumped at the harbor entrance and in the harbor in the vicinity of sampling site 5. In figures 11 to 18 bands 5 and 7 imagery is shown which indicates areas of high dye concentration. The dye in the harbor area is difficult to see while that at the breakwall entrance is easily seen in the band 5 imagery. In reference 2 it is shown that the dye could be detected at concentrations as small as 1 PPB. Computer analysis of our multispectral data must be made to determine the sensitivity of the scanner. The final data will be only relative and will require the C.W.R.U. data in order to be put on an absolute basis.

Temperature Distribution

Band 11 thermal infrared imagery for July 25, 28, and 29 are shown in figures 19 to 21. Included with each image is a gray scale with the temperature corresponding to each shade of gray in the scale and in the image This can be done because the band 11 detector views two known temperature sources during each rotation of the scan mirror. In order to apply this calibration to the scene below, air absorption must be accounted for (ref. 3). This effect causes the indicated surface tempera-

ture from 5000 feet to be approximately 3^{o} C low depending on atmospheric conditions. The surface temperature differences should be given accurately by the gray scale.

The warm water plumes shown in figures 19 and 20 are similar in structure to the sediment plumes shown previously. As a general comment on the images, there appears to be little warm water flowing from the river mouth compared to that from the Cleveland Municipal Power Plant. During the time of the flights the land was much warmer than the water and therefore most land temperature variations are beyond the dynamic range of the film and are lost in the images. These land-temperature variations are contained in the data and could be displayed at the expense of losing the small temperature variations in the water.

SUMMARY OF RESULTS

Imagery made from multispectral scanner data taken during the Cleveland Harbor Study has been presented. The images provide a synoptic view of the study area and show the areas of high water reflectance due to high sediment loading.

Since the area was overflown repeatedly, a number of images of the study area were obtained. These showed that the sediment distribution can change in a few hours due to wind direction or other changes.

During the time of the study when a high concentration of Rhodamine B dye was present in the harbor area, the dye could be seen in images using bands 4, 5, and 6. In very high concentrations the dye area was darker than the surrounding water which dramatically demonstrated the nonlinearity of reflectance with dye concentration. Low concentrations of dye could not be distinguished from the sediment plume using film images.

It will be necessary to use computer analysis such as classification or band subtraction to investigate the dye plume and sediment plume in a quantitative manner.

Thermal infrared images for three of the days during the study showed the thermal plume from the Cuyahoga River. The river plume was significantly smaller than the plume from the Cleveland Municipal Power Plant, which could also be seen in the images.

REFERENCES

1. Svehla, Roger, et al.: Remote Sensing Study of Maumee River Effects on Lake Erie. NASA TM X-71780, 1975.

2. Eliason, J. R.; Foote, H. P.; and Doyle, M. J.: Surface Water Movement Studies Utilizing a Tracer Dye Imaging System. Proceedings of the Seventh International Symposium on Remote Sensing of Environment, Vol. 1, Univ. of Michigan, 1971, pp. 731-748.

3. Boudreau, Robert D.: Correcting Airborne Scanning Infrared Radiometer Measurements for Atmospheric Effects. NASA TM X-69940, 1972.

TABLE I. - SUMMARY OF ACTIVITIES

Date	Number of data flight lines	Ship operation		
		Hydra (OSU)	CWRU boat	NASA boat
7/17	4		(Dye dumped)	
7/18	13			
7/24	4			
7/25	22	X	(Dye dumped)	
7/26	20	X	X	X
7/27	12	X	X	
7/28	27	X	(Dye dumped)	X
7/29	21	X	X	X

TABLE II. - INSTRUMENT AND FLIGHT LOG

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 34	7/17	1442 1504 1505	1	1500 E→W	---	1500	135	26 4.7		Wheels up Late start.	
		1509 1513	2	1500 W→E	---	1500	142	40 4.7		[Plume moving to west; no dye apparent]	Hot sultry day; fairly uniform, hazy sky. Much haze.
		1519 1523	3	1500 W→E	---	1500	139	36 4.7			
		1530 1534	4	1500 W→E	---	1500	142	57 4.3			
		1545							Some shots taken	Wheels down	
WQ 35	7/18	942								Wheels up	
		1002 1005	1	1015	0.7 L	6000	140				
		1014 1017	2	1015	1.0 R	6000	133				Bright hazy sky; no clouds, much haze

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 35	7/18	1026 1029 1035	3	1015	2.7 R	6000	130			Channels not working well Replace ch. 5 card; update INS	
		1045 1047	4	1115	1.0 L	1500	133				
		1054 1056	5	1115	0.5 L	1500	134	33 4.7			
		1103 1105	6	1115	0.0	1500	126	26 4.7			
		1110 1111	7	1115	0.5 R	1500	126	36 4.7			
		1118 1120	8	1115	1.0 R	1500	120	?		[Some problems with ch. 11; BB(LO) jumping around throughout later part of flight.]	
		1126 1128	9	1115	1.5 R	1500	130				
		1133 1135	10	1115	2.0 R	1500	132				
		1140 1142	11	1115	2.5 R	1500	135				
		1147 1149	12	1115	3.0 R	1500	135				

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 35	7/18	1155 1157	13	1115	3.5 R	1 500	138				
		1205								Wheels down.	
WQ 36	7/24	907								Wheels up.	
		943 945	1	H1000	1.0 L	1 500	118	22 5.7			
		951 953	2	H1000	0.5 L	1 500	123	21 5.3			
		959 1002	3	H1000	0	1 500	124	30 5.3			Very hazy, overcast
		1007 1010	4	H1000	0.5 R	1 500	121	37 5.3			
		1025								Wheels down.	
WQ 37A	7/25	842								Wheels up.	
		909 915	1	H0915	0.0	10 000	117	20 30.0		[Plume moving toward east]	
		919 921	2	H0915 (Rev)	0.5 R	10 000	180	13 20.0			
		926 931	3	H0915	0.5 L	10 000	118	22 22.0			Only scattered high clouds.

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 37A	7/25	939 945	4	H0915	2.4 R	10 000	120	19 17.0		[Winds directly toward shore]	Only scattered high clouds; crisp and clear, one of best days
		959 1004	5	H1015	1.2 L	5 000	135	87 12.0			
		1010 1014	6	H1015	0.3 R	5 000	132	22 11.6		[Dye dumped ~1010]	
		1015 1016	7	~H1015 (Rev)		5 000		8 10.0		Mini-F.L.	
		1021 1025	8	H1015	1.8 R	5 000	131	22 12.3			
		1027 1028	9	~H1015 (Rev)		5 000		? 10.0		Mini-F.L.	
		1032 1036	10	H1015	3.3 R	5 000	136	-			
		1038 1039	11	~H1015		6 500 (Climb)		? 10.0		Mini-F.L.	
		1047 1052	12	H1100	0.6 L (Right over harbor)	10 000	127	19 20.0		Dye "glob" moved ~1/3 of distance across harbor.	
		1055 1056	13	~N→S		10 000	---	-		Mini-F.L.	

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 37A	7/25	1100 1105	14	H1100	2.3 R	10 000	121	23 20.0			
		1120								Wheels down.	
WQ 37B	7/25	1505								Wheels up.	
		1524 1526	1	H1545	Var	5 000	153	13 13.7			
		1535 1539	2	H1545	0.0- 0.8 L	5 000	150	20 13.7			
		1551 1555	3	H1545	1.3 L	5 000	153	22 13.7		Update ins at crib.	
		1607 1609	4	C1615	1.3 L	5 000	152	7 13.7			
		1614 1616	5	C1615	1.3 L	2 500	152	22 4.3			
		1622 1624	6	C1615	1.3 L	1 000	147	33 2.7			
		1632 1635	7	H1645	1.3- 1.6 L	5 000	160	16 10.3			
		1644 1647	8	H1645	2.8 L	5 000	157	14 12.3			
		1658								Wheels down.	
WQ 38A	7/26	843								Wheels up.	
		902 908	1	H0915	0.1 R	10 000	140	15 22.0	I22		

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 38A	7/26	918 922	2	H0915	2.9 R	10 000	149	12 22.0	I23-75		
		932 934	3	C0945	1.1 R	10 000	146	4 22.2			Very clear day, much like 7/25 am; perhaps even clearer
		943 945	4	C0945	1.5 R	5 000	141	10 13.2	I27-28		
		947								Update ins at crib	
		952 953	5	C0945	0.1 L	500	152	28 1.3			
		1007 1010	6	H1030	0.2 L	5 000	149	20 11.0			
		1017 1020	7	H1030	1.3 R	5 000	147	12 13.7			
		1027 1030	8	H1030	2.8 R	5 000	146	15 13.7			
		1040 1043	9	H1030	4.3 R	5 000	143	15 13.7			
		1045								Update ins at crib	
		1055 1059	10	H1100	0	10 000	138	11 23.0			
		1107 1110	11	H1100	2.9 R	10 000	139	8 23.0	I34,35		
		~1120								Wheels down.	

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 38B	7/26	1509								Wheels up.	
		1529 1533	1	H1530	0.2 L	10 000	165	11 25.7	II1-4		
		1543 1547	2	H1530	3.1 L	10 000	168	10 23.7			
		1601 1604	3	H1600	1.3- 1.6 L	5 000	154	18 12.7			Very clear skies, just like a.m.
		1614 1617	4	H1600	3.1 L	5 000	159	18 12.7			
		1620								Update ins at crib.	
		1628 1632	5	H1630	0.0- 0.1 L	10 000	169	10 21.7	II5-6		
		1640 1643	6	H1630	2.4 L	10 000	166	10 21.7			
		1653 1654	7	C1700	-					[little wind, if any]	
		1702 1703	8	C1700	1.1 L	5 000	159	12 10.0			
		1709 1710	9	C1700	1.3 L 14° L TKE	500	123	55 1.7			
		1720								Wheels down.	
WQ 39A	7/27	~940								Wheels up.	
		1001 1004	1	H1015	0.6 L	5 000	127	16 14.7			

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ39A	7/27	1011 1015	2	H1015	0.9 K	5 000	127	14 14.7			
		1022 1027	3	H1015	2.4 R	5 000	129	11 13.7			Generally clear day, some haze.
		1036 1037	4	C1045	0.6 L	5 800	1[illegible]7	10 14.7			
		1047 1048	5	C1045	0.6 L	2 000	129	20 4.2			
		1054 1055	6	C1045	~0.5 L	500	126	34 1.6			
		1104 1106	7	H1115	~0.5 R 15° L TKE	2 000	118	35 4.4	II8-9		
		1116 1119	8	H1115	~0.6 R 10° L TKE	5 000	128	17 11.6	II10-11		
		1129								Wheels down.	
WQ 39B	7/27	1508								Wheels up.	
		1521 1524	1	H1530	0.9 R	5 000	164	26 10.0			
		1535 1538	2	H1530	0.8 R	5 000	164	24 11.0		Rough seas, impossible to see plume.]	
		1549 1553	3	H1530	1.6 R	2 000	155	53 5.0			Slightly improved visibility, but many more clouds.

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
		1603	4	H15[illegible]0	1.3 L	2 000	154	12			
WQ 39B	7/27	1604		(Overcrib)				5.2			
		1614								Wheels down.	
WQ 40A	7/28	851								Wheels up.	
		918	1	C0930	0.8 L	10 000	130	14	II12-13	Dye visible.	
		921						25.5			
		926	2	H0930		10 000	176	14			Clear day with some haze. Visibility 15-20 mi. However not as clear as 7/26.
		929						20.0			
		938	3	C0930		5 000	147	31	II14-15		
		940						10.0			
		943	4	H0945		5 000	155	17			
		946						10.0			
		955	5	C0945		500	134	131			
		956						1.7			
		1000	6	H1000		1 500	142	43			
		1002						4.3			
		1012	7	H1015	0.1 L	5 000	144	20			
		1015						12.7			
		1023	8	H1015	1.3 R	5 000	139	20	II16		
		1026						12.7			
		1034	9	H1015	2.8 R	5 000	136	19	II17		
		1038						12.7	II18		
		1046	10	H1015	4.3 R	5 000	139	11			
		1049						12.7			
		1053	11	H1100	0.2 L	3 000	167	31			
		1055						4.8	II19		

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 40A	7/28	1058 1101	12	H1100	0.8 R 21° L TKE	1 500	145	36 4.3	II21 II22		
		1112 1115	13	H1100	1.8 R	5 000	142	? 14.3			
		1120								Wheels down.	
WQ 40B	7/28	1241								Wheels up.	
		1300 1303	1	H1300	0.5 R	5 000	125	13 14.3			
		1307 1311	2	H1315	~90° TKE (E→W)	5 000	137	20		F.L. 2-4 at ~90° to Sun.	
		1319 1322	3	H1315	106° L TKE	3 000	126	25 7.5			Very bright, some haze.
		1328 1331	4	H1315	~98° L TKE	3 000	128	33 8.5			
		1337								Wheels down.	
WQ 40C	7/28	1508								Wheels up.	
		1522 1526	1	H1530	0.2 L 5°-6°L TKE	5 000	150	21 13.3	II27	Very little wind.	
		1536 1540	2	H1530	1.3 L	5 000	146	23 13.3	II28-29		

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 40C	7/28	1552 1556	3	H1545	0.1 R	10 000	165	12 24.2			Quite clear; visibility slightly better than a.m.
		1606 1607	4	C1600	0.0	10 000	170	4 23.1			
		1616 1617	5	C1630	0.1 L	5 000	152	8 13.2			
		1622 1623	6	C1630	0.3 L 10° L TKE	1 500	155	25 2.5			
		1628 1629	7	C1630	0.3 L	500	149	55 1.4			
		1637 1637	8	C1630	---	100	148	52 0.6			
		1647 1650	9	H1645	0.1 R	5 000	160	21 12.8		Wind out of west	
		1656 1659	10	H1645	0.8 L	5 000	154	17 12.8			
		1710								Wheels down.	
WQ 41A	7/29	840								Wheels up.	
		859 902	1	H0915	0.2 L	5 000	143	12 14.7		Little or no wind.	
		911 912	2	C0915	1.0 R	5 000	147	10 13.7			

TABLE II. - Continued.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 41A	7/29	923 924	3	C0915	0.6 R	2 000	132	18 6.3			Clear skies, considerable haze; thick cloud from Muny drifting over harbor.
		931 932	4	C0915	0.4 R	500	109	10 1.8			
		943 945	5	H1000	1.1 L	2 000	134	30 6.5			
		954 957	6	H1000	0.7 L	2 000	133	25 6.5			
		1006 1009	7	H1000	0.1 L	2 000	132	27 6.5			
		1018 1021	8	H1000	0.4 R	2 000	132	25 6.5			
		1030 1033	9	H1000	1.1 R	2 000	134	29 5.8			
		1040 1043	10	H1000	1.7 R	2 000	135	32 5.8			
		1053 1056	11	H1100	0.3 R 5° L TKE	5 000	145	15 13.7			
		1105 1107	12	H1100	1.0 L	5 000	145	12 13.7			
		1118								Wheels down.	
WQ 41B	7/29	1518								Wheels up.	
		1530 1534	1	H1530	0.1 R 4° TKE	5 000	141	17 14.6			

TABLE II. - Concluded.

Flight designation	Date	Time	Run	Flight line from fig. 1	Offset right or left from flight line, n mi	Altitude, ft	Ground speed, knot	Camera frame number and time interval, sec	Camera notes	Notes	Weather
WQ 41B	7/29	1542	2	H1530	0.9 L	5 000	145	16			
		1545						13.7			
		1548								Ship moving out of harbor	
		1552	3	H1600 3° R TKE	0.6 R	1 900	145	34			Clear skies with haze. Wind has cleared the air a bit relative to a.m. flight.
		1554						5.4			
		1601	4	H1600	0.1 R	2 000	133	53		NE wind	
		1604						6.3			
		1611	5	H1600	0.5 L	2 000	132	35			
		1615						5.5			
		1617									
		1622	6	C1630	0.1 L	500	124	22			
		1623						1.6			
		1628	7	C1630	0.0	2 000	134	14			
		1629						5.8			
		1637	8	C1630	0.1 L	5 000	148	7		Getting hazier.	
		1638						13.7			
		1643	9	H1645	0.1 L	5 000	140	18			
		1647						14.6			
		1700								Wheels down.	

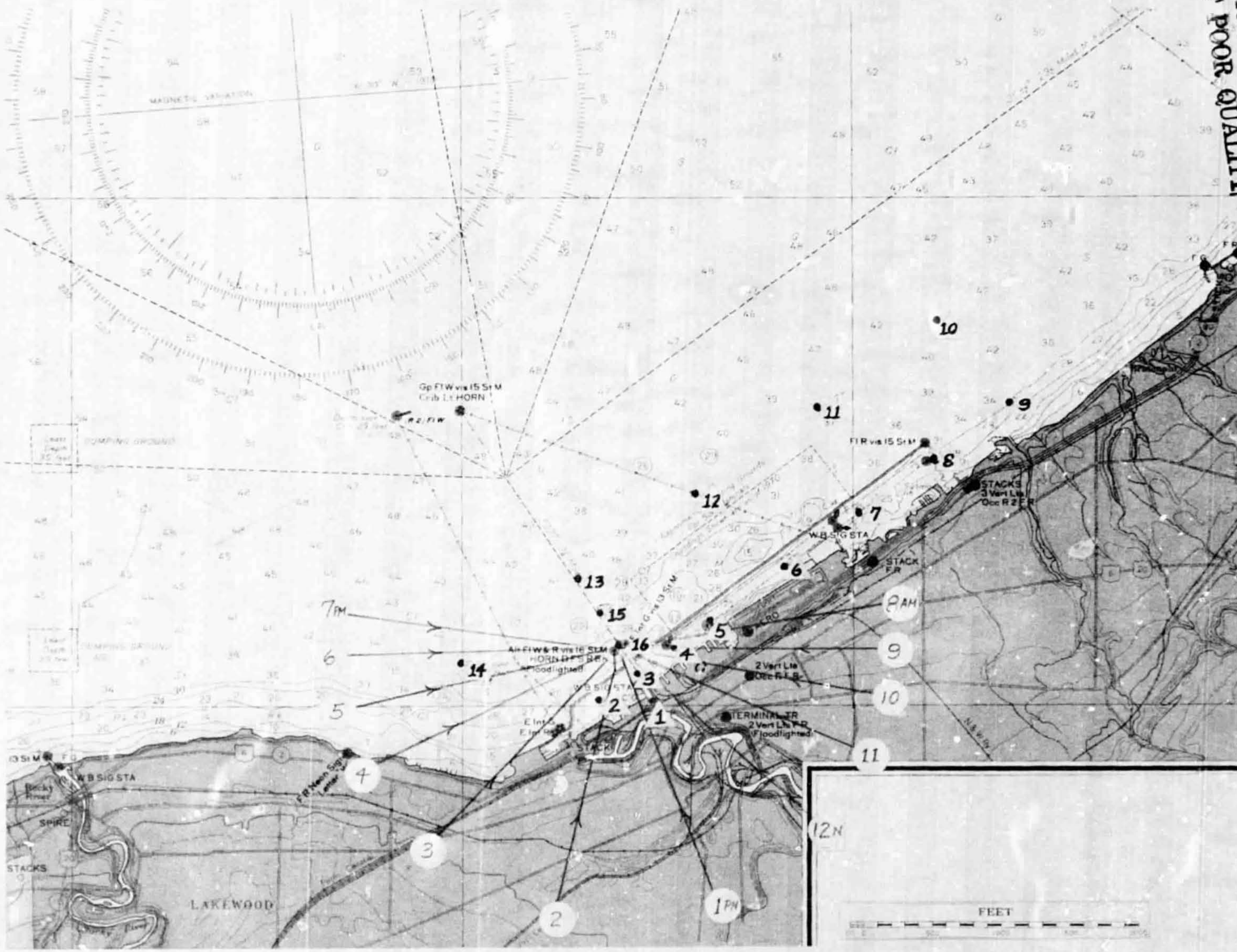


Figure 1. - Cleveland area of Vermilion, Ohio chart showing numbered sampling stations and flight lines for the indicated time of day.

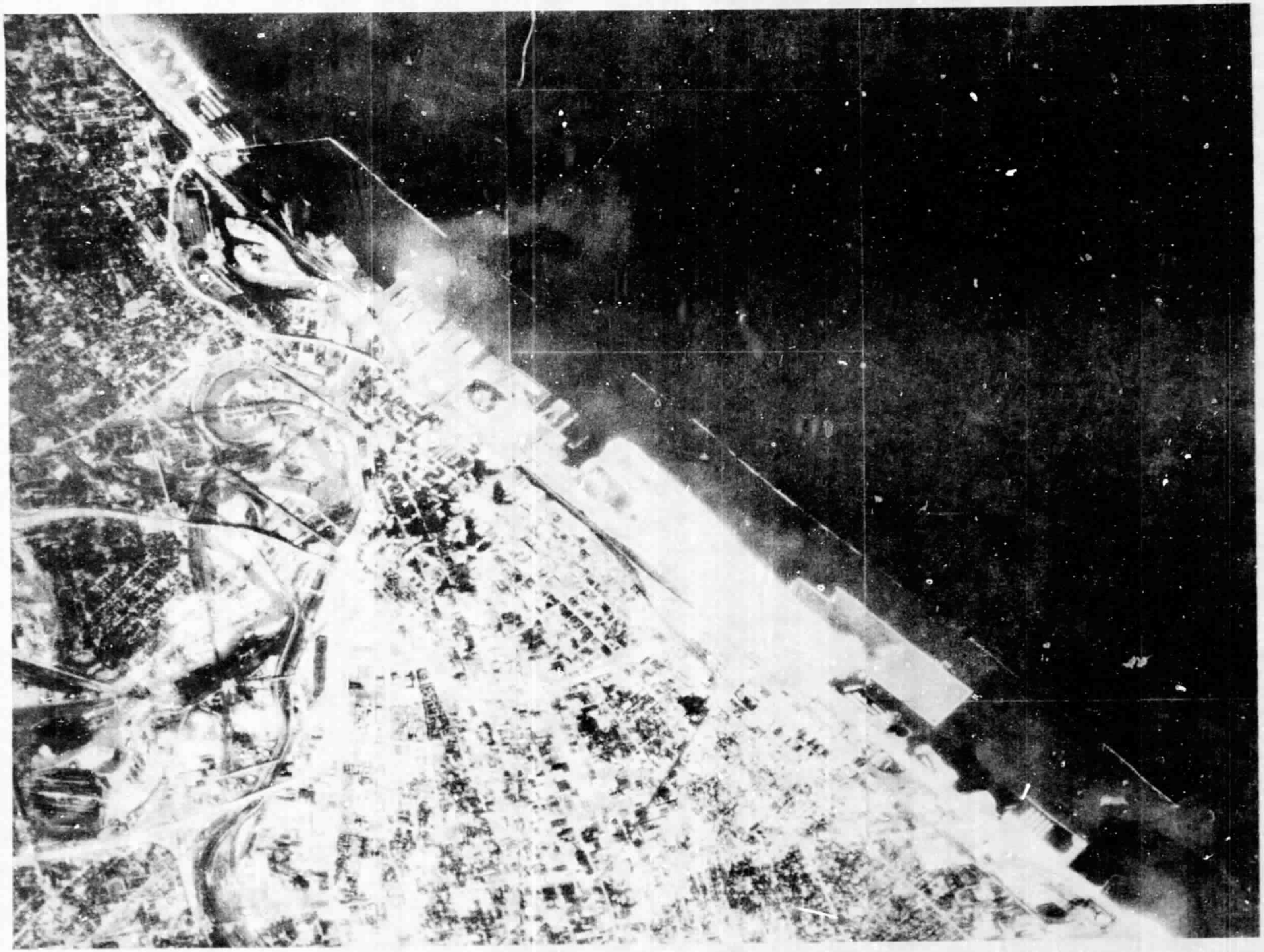


Figure 2. - 7/25/75, Runs 6, 7, and 8, 10:15 AM Band 4

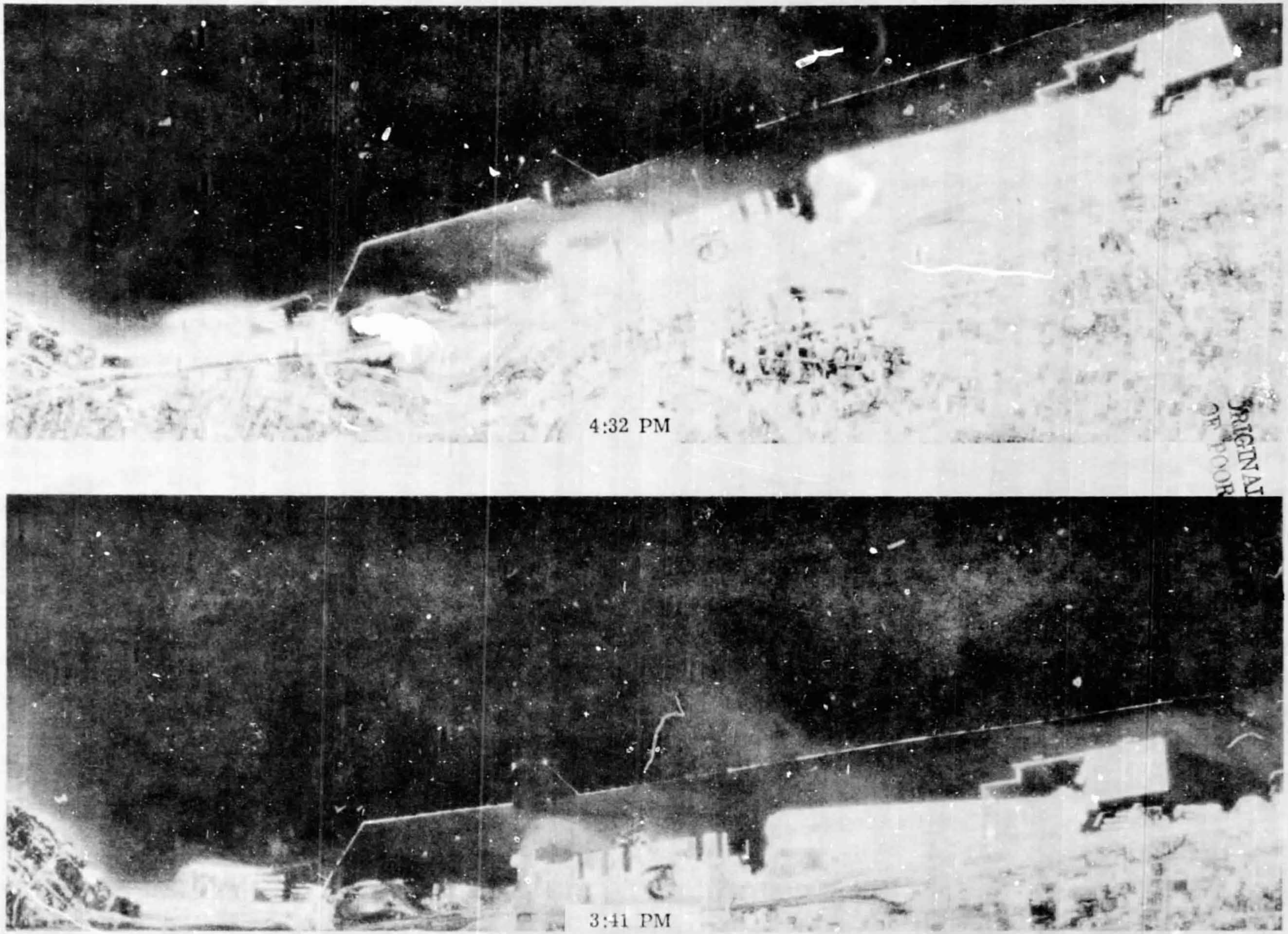
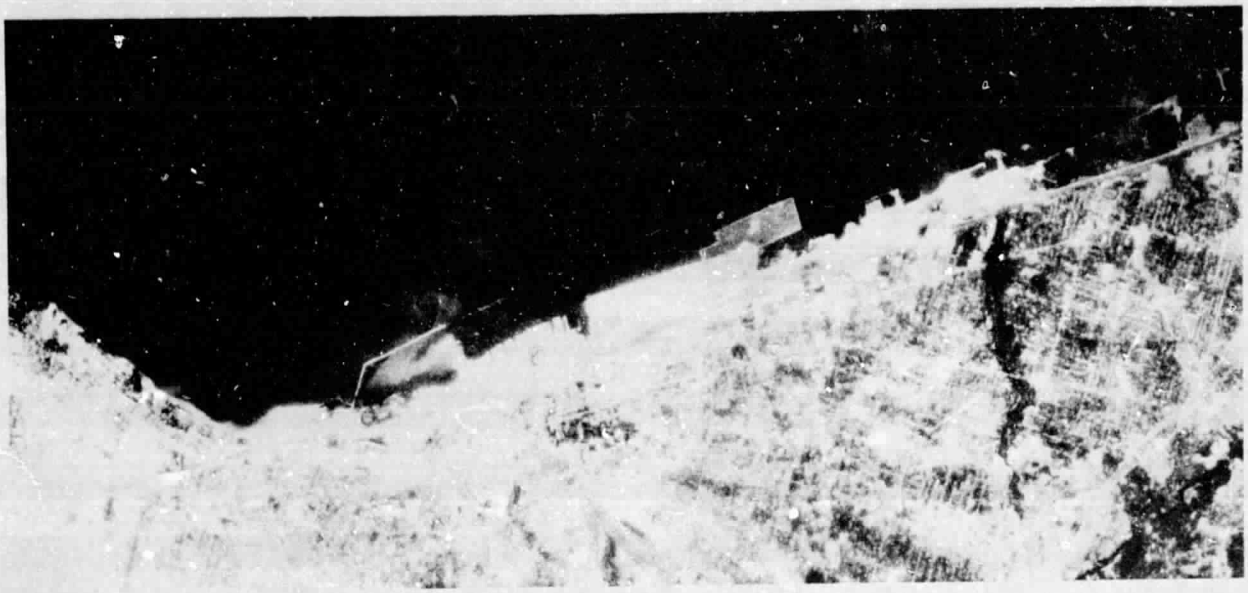


Figure 3. - 7/25/75, Band 6

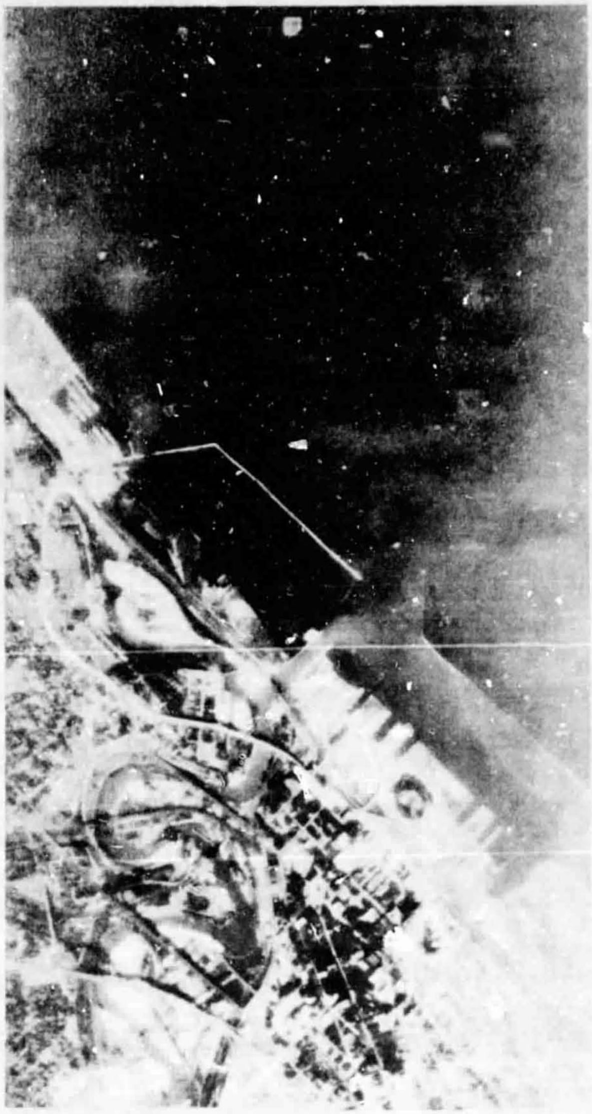


4:03 PM, 10,000 ft. Altitude

4:24 PM, 5,000 ft. Altitude

Figure 4. - 7/26/75, Band 4

Band 4



Band 7

Figure 5. - 7/27/75, 10:02 AM

ORIGINAL PAGE IS
OF POOR QUALITY

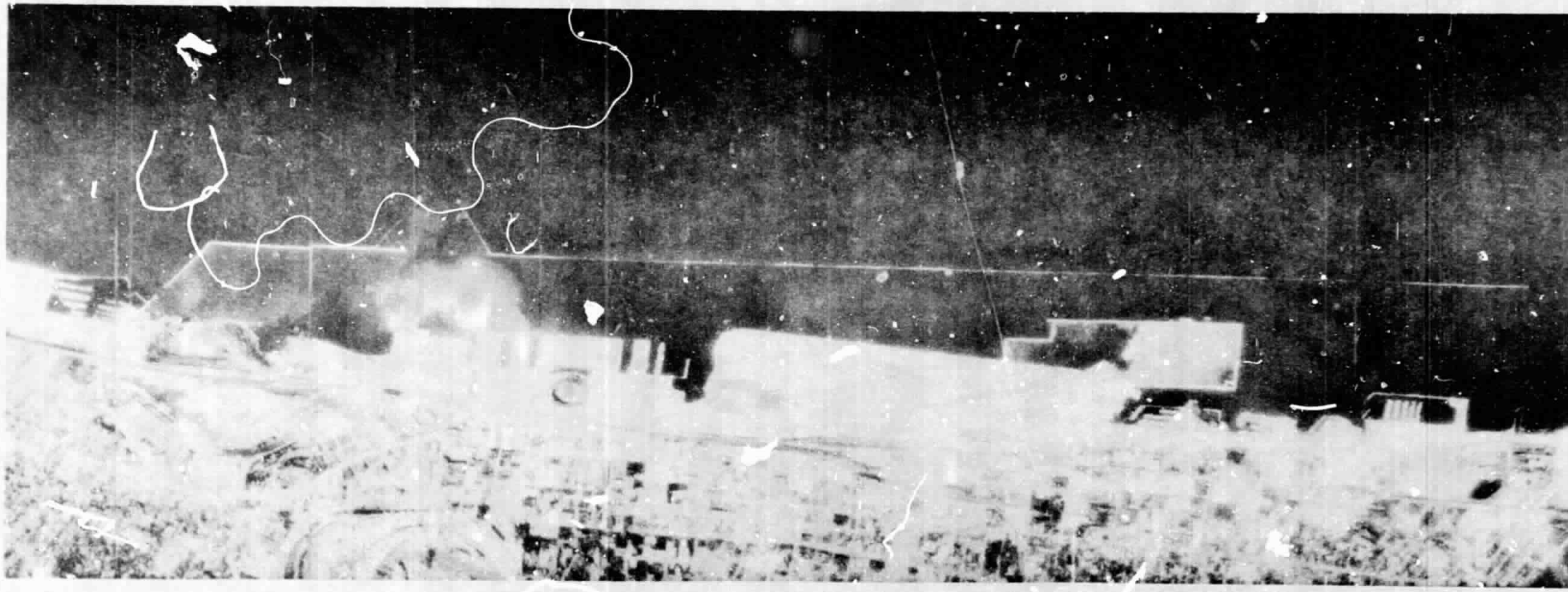
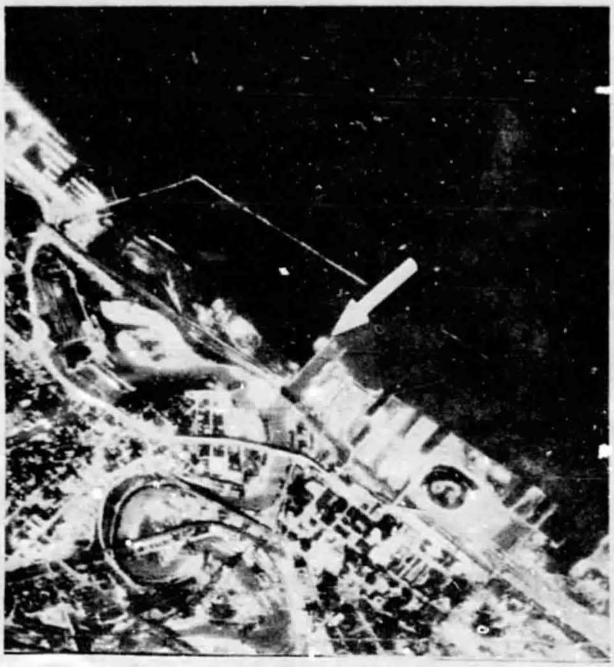


Figure 8. - 7/28/75, 3:24 PM, Band 5

Figure 7. - 7/29/75, 3:30 PM, Band 4

Band 4, 10:15 AM

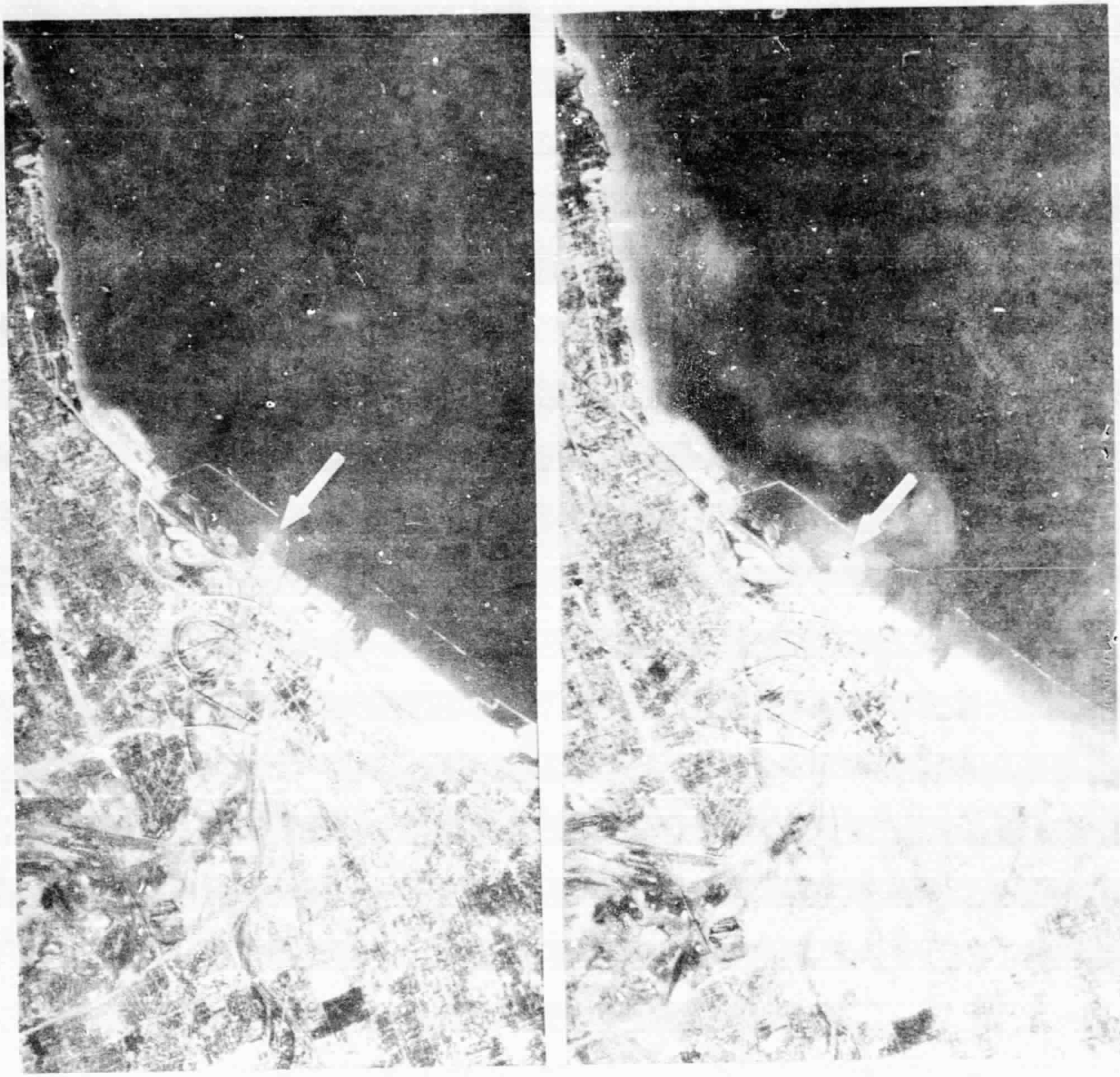


Band 5, 10:27 AM

Band 4, 10:38 AM

Figure 8. - 7/25/75

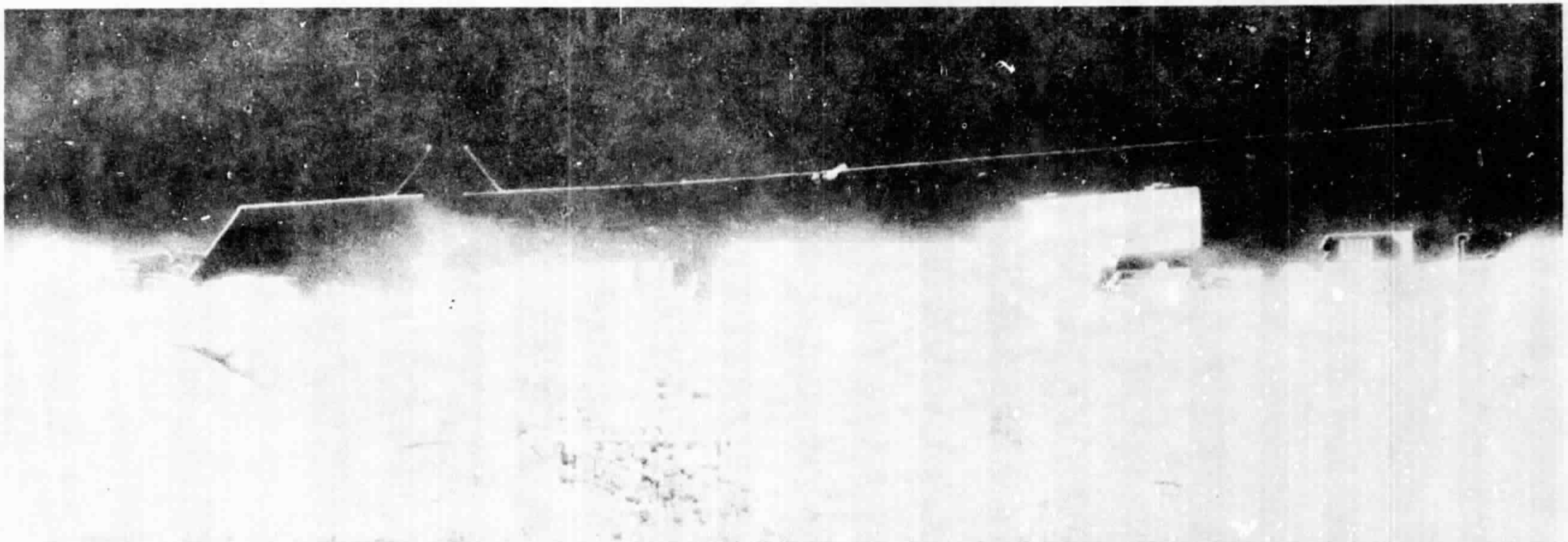
F-8550



Band 5

Band 4

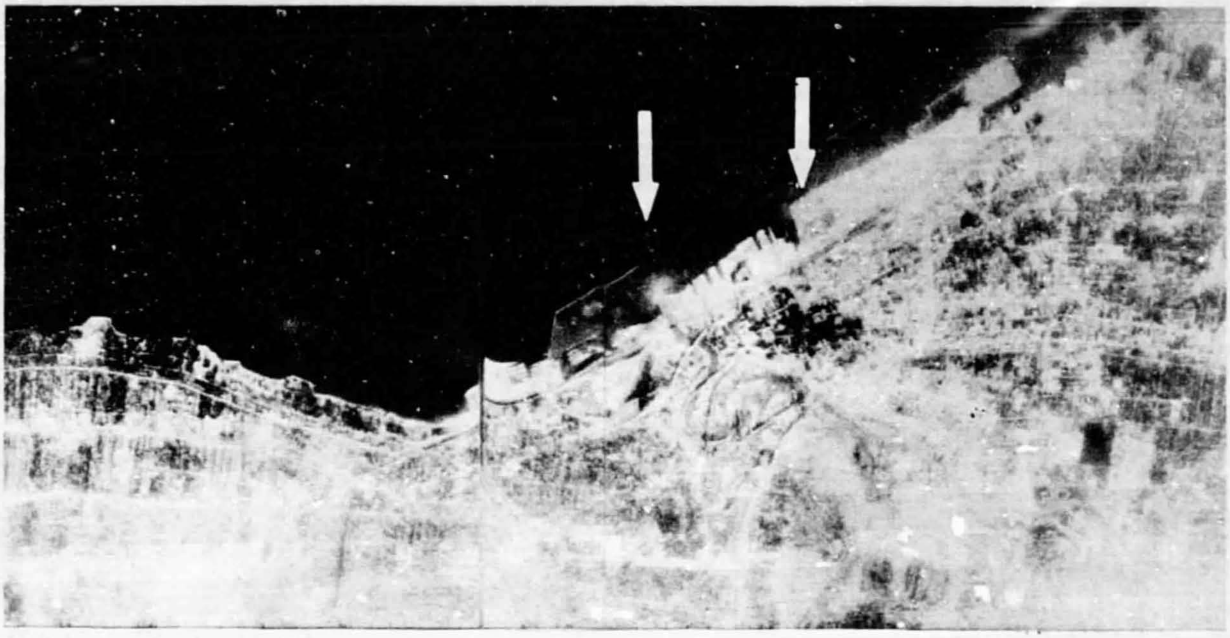
Figure 9. - 7/25/75, 10:50 AM



Band 8

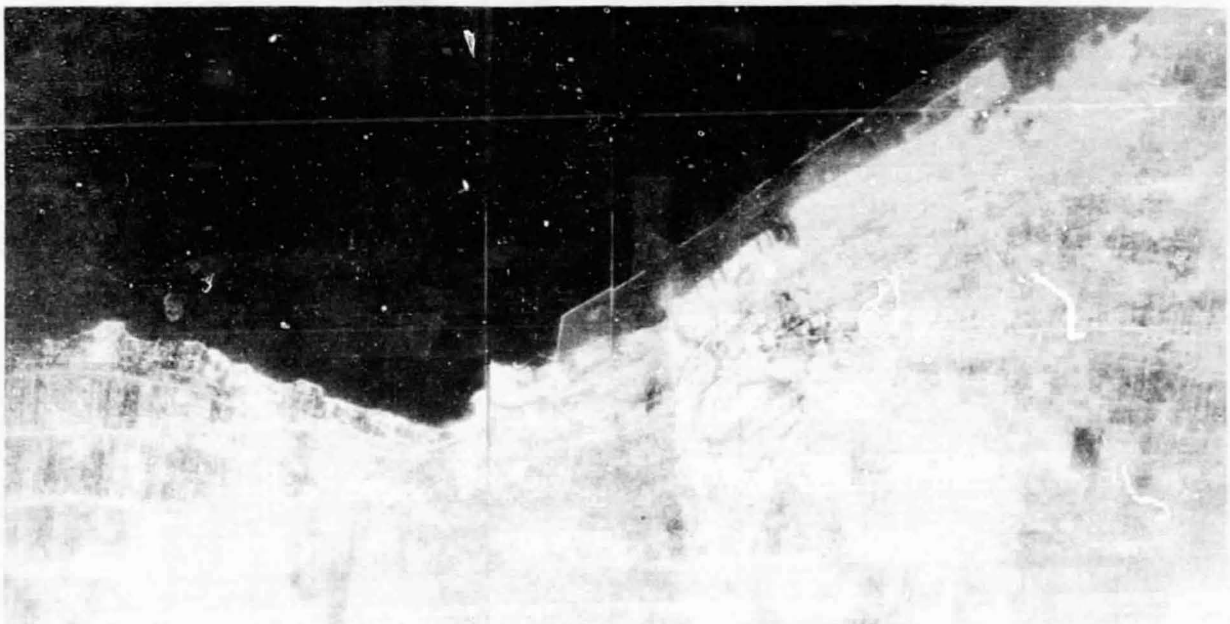
Band 4

Figure 10. - 7/25/75, 3:35 PM



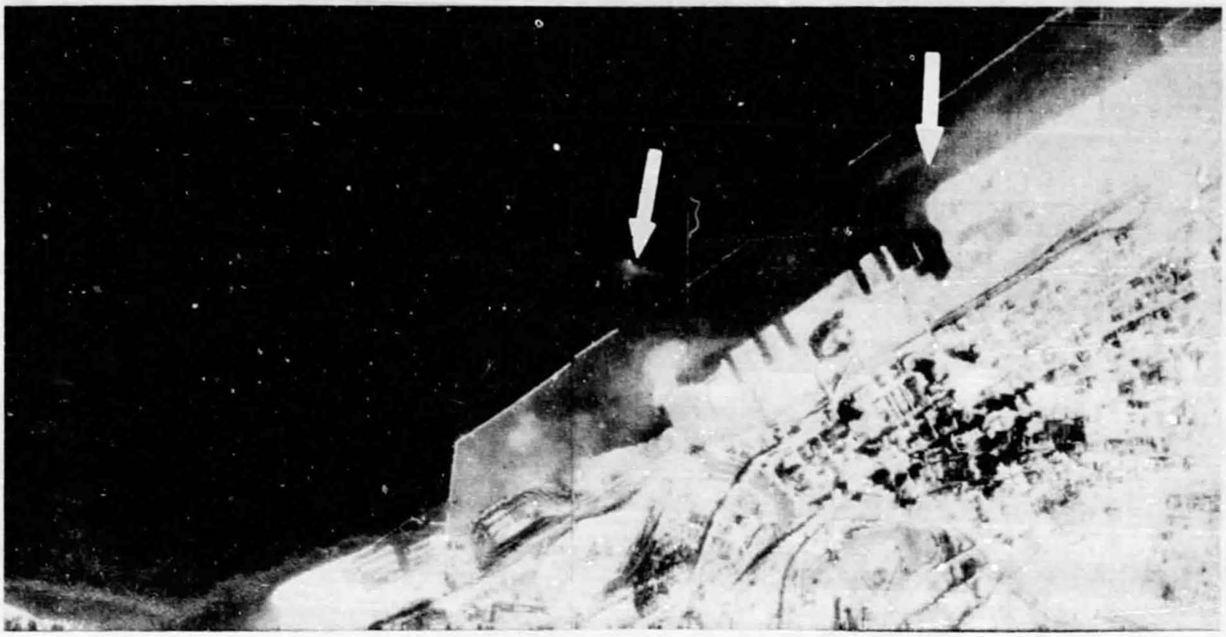
Band 5

E-8550

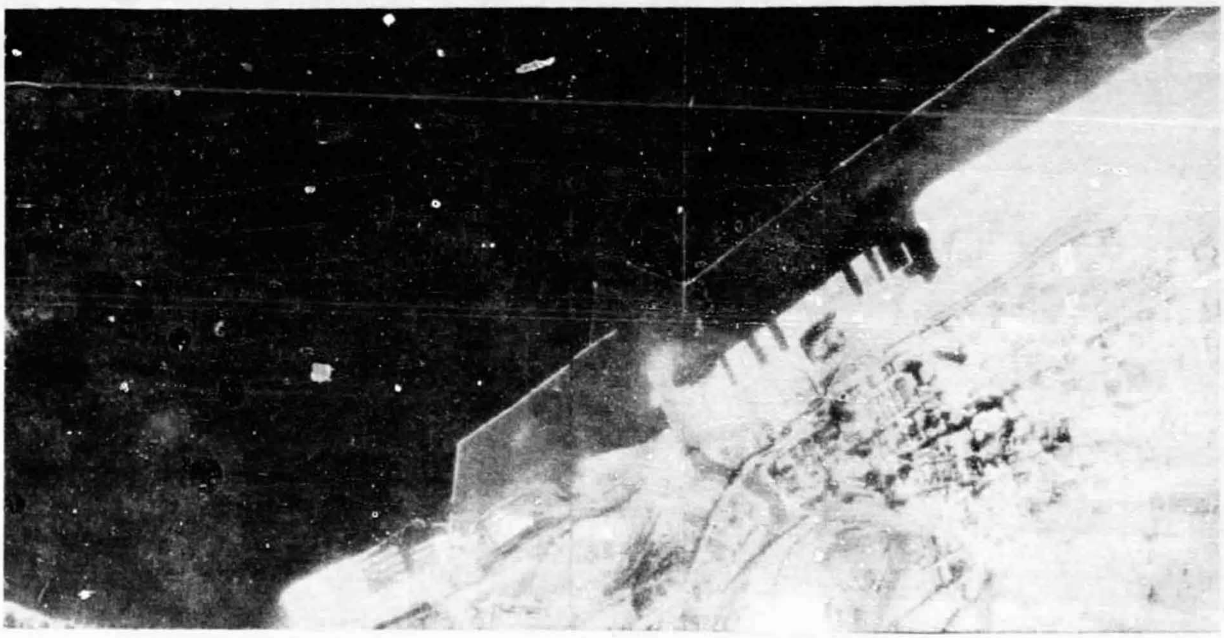


Band 7

Figure 11. - 7/28/75, 9:28 AM

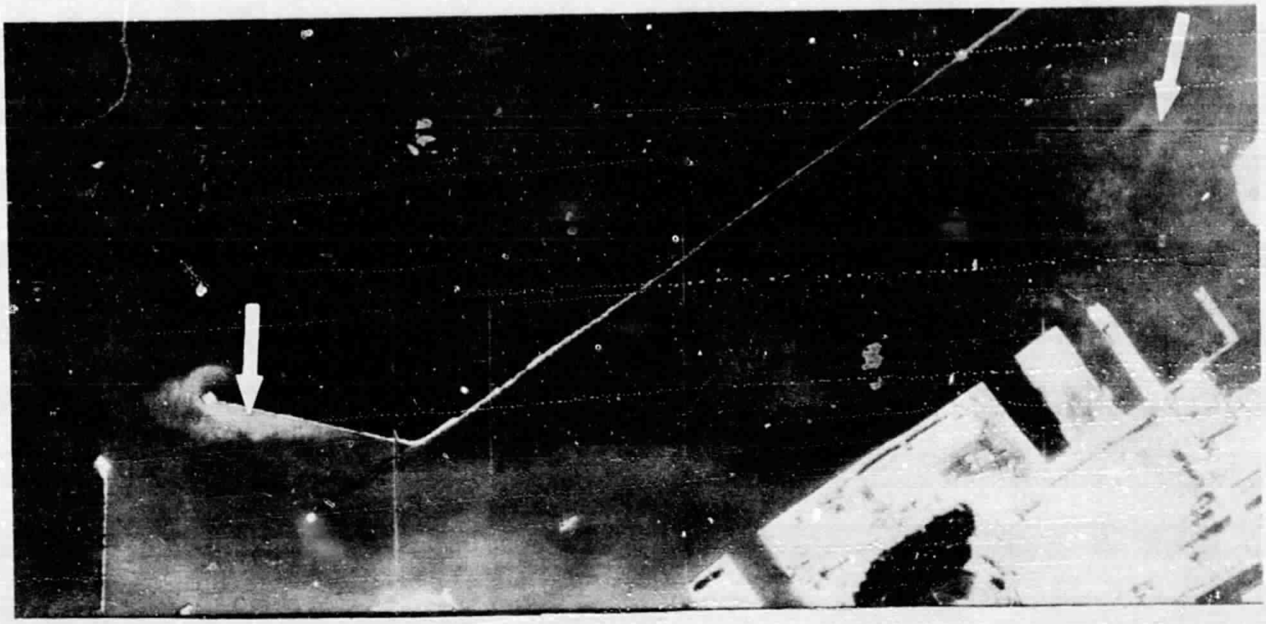


Band 5

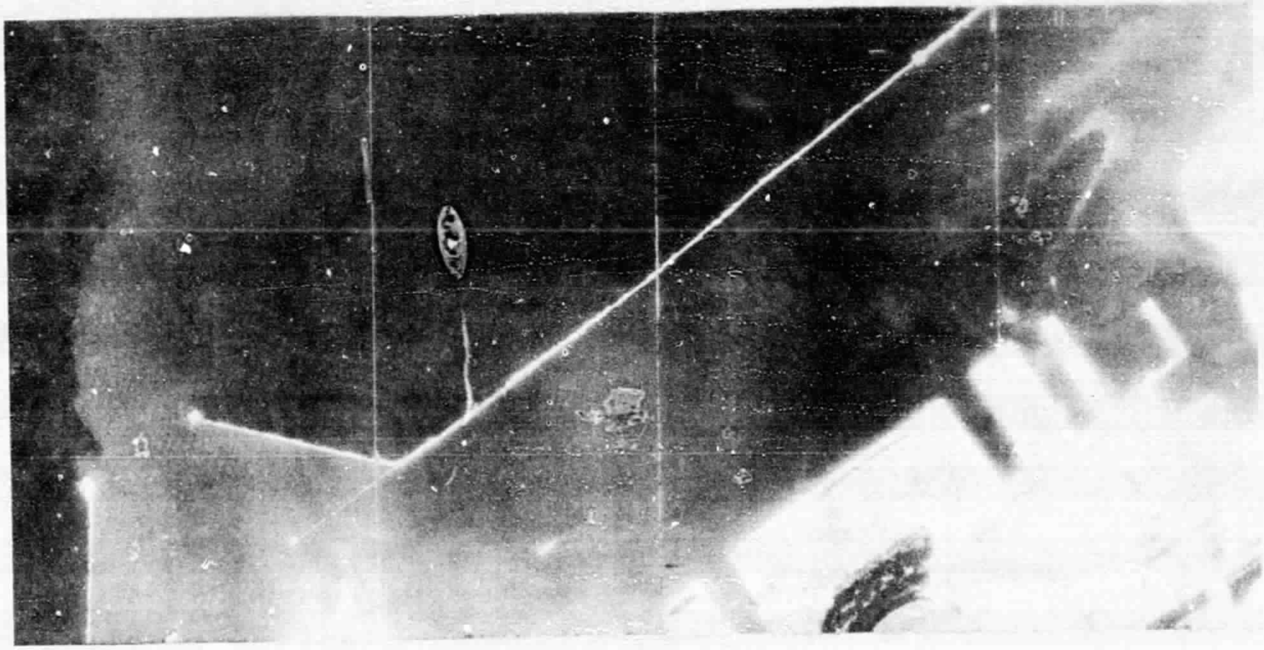


Band 7

Figure 12. - 7/28/75, 9:45 AM



Band 5

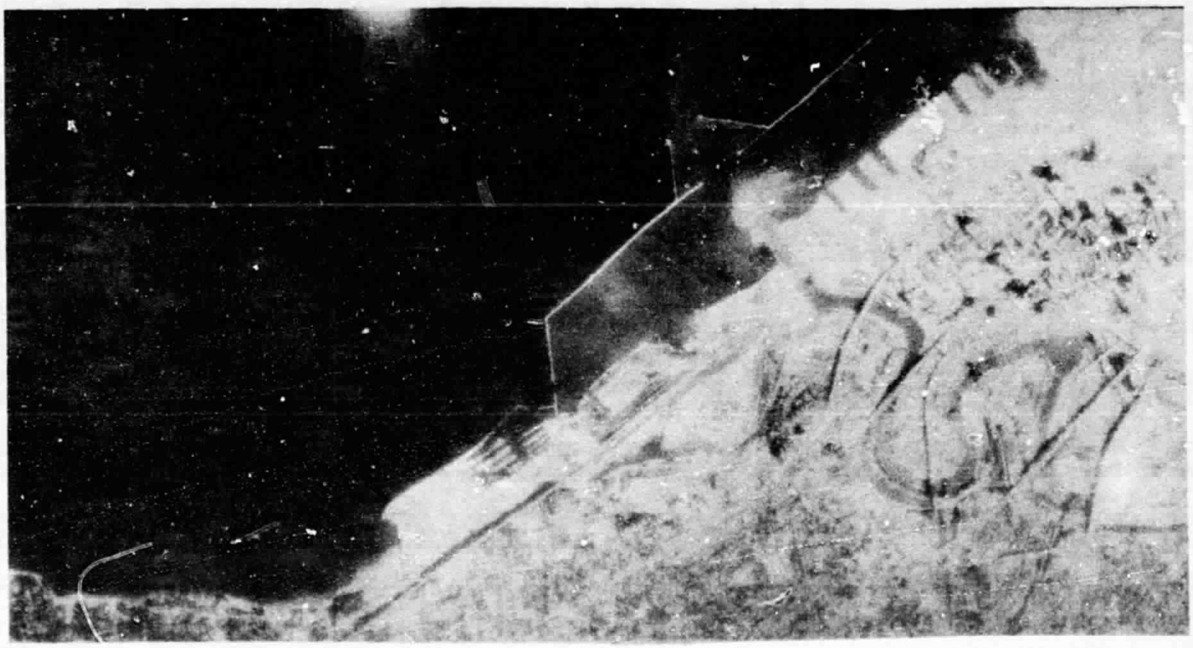


Band 7

Figure 13. - 7/28/75, 10:01 AM

E-8550

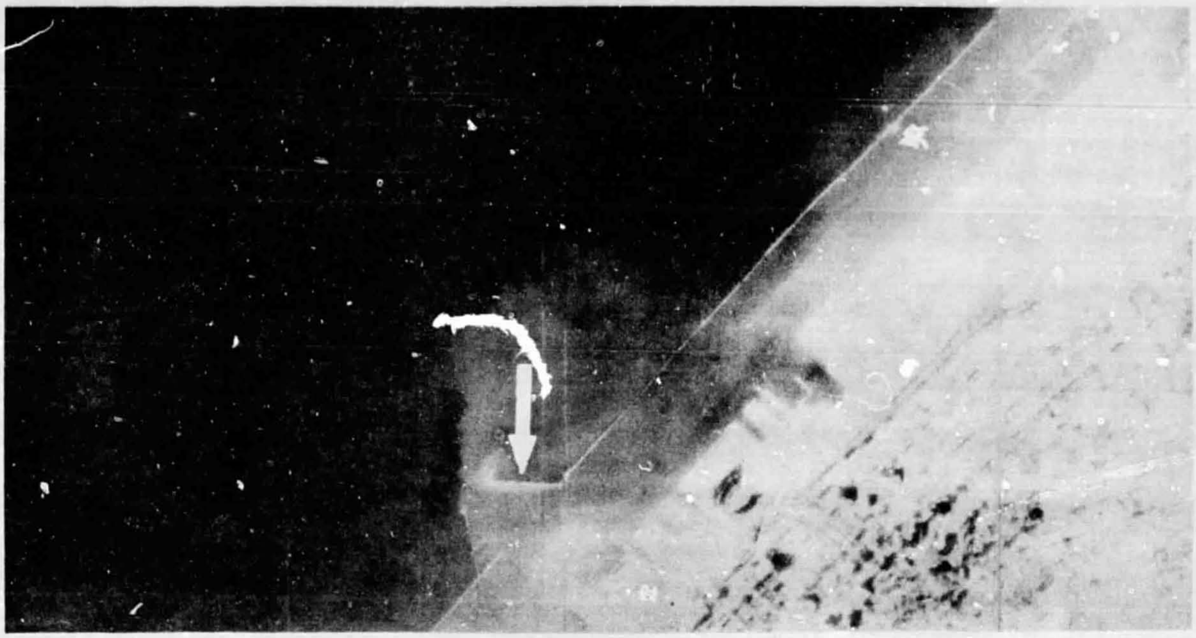
Band 5



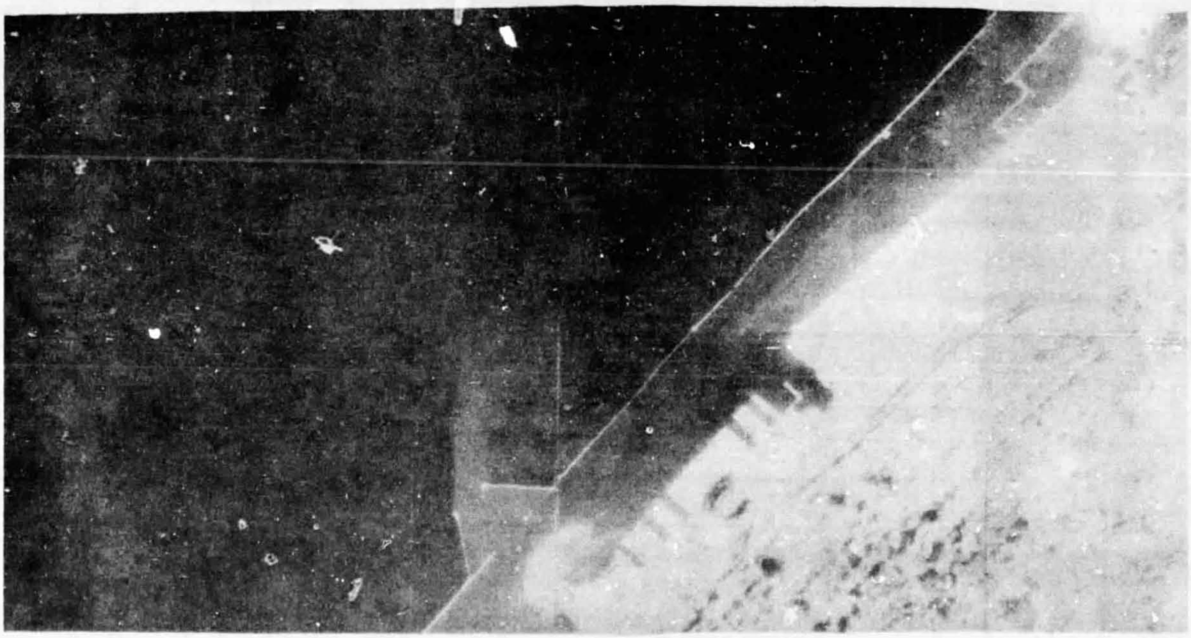
Band 7

Figure 14. - 7/28/75, 10:13 AM

E-8550

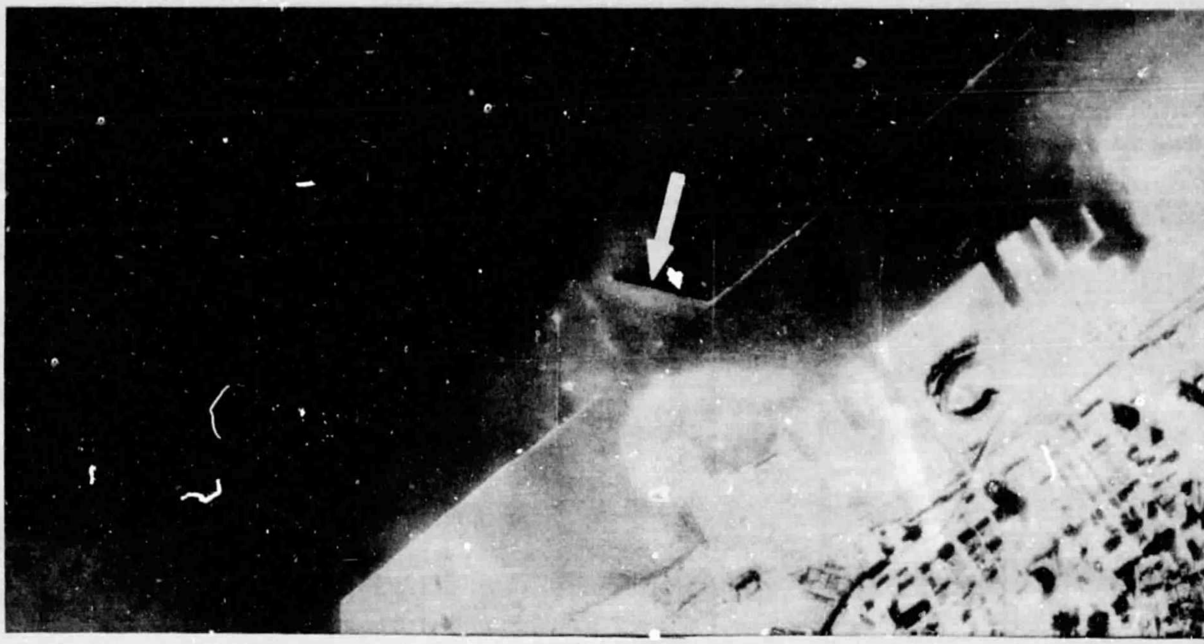


Band 5



Band 7

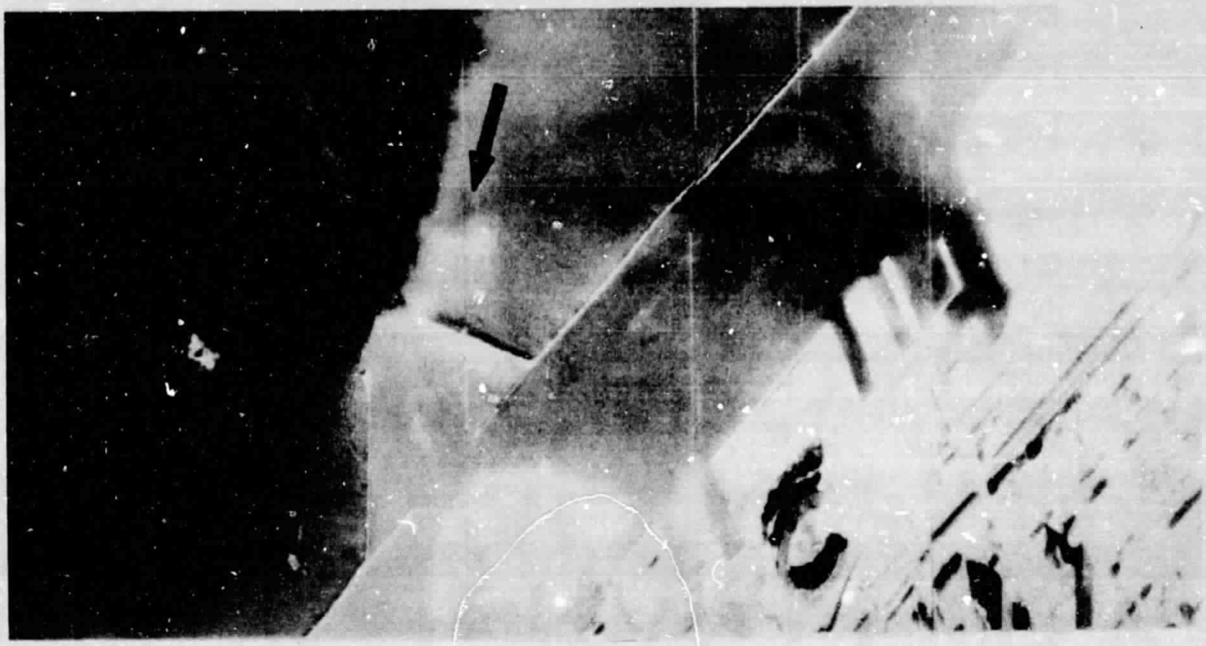
Figure 15. - 7/28/75, 10:25 AM



Band 5

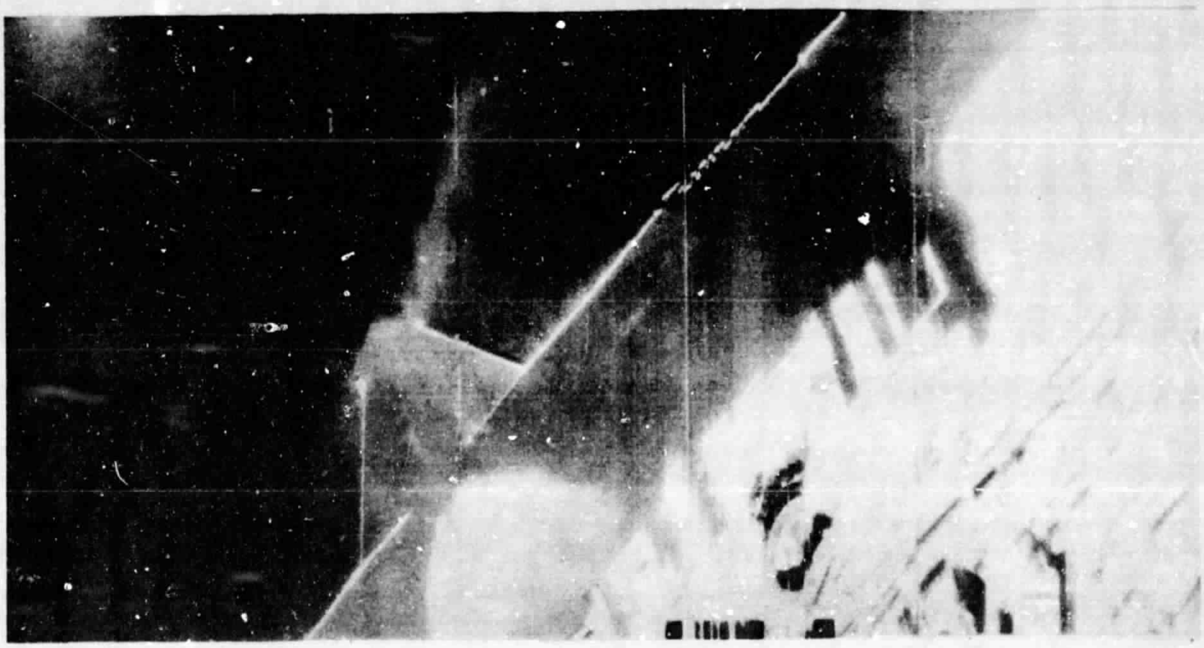
Band 7

Figure 16. - 7/28/75, 10:54 AM



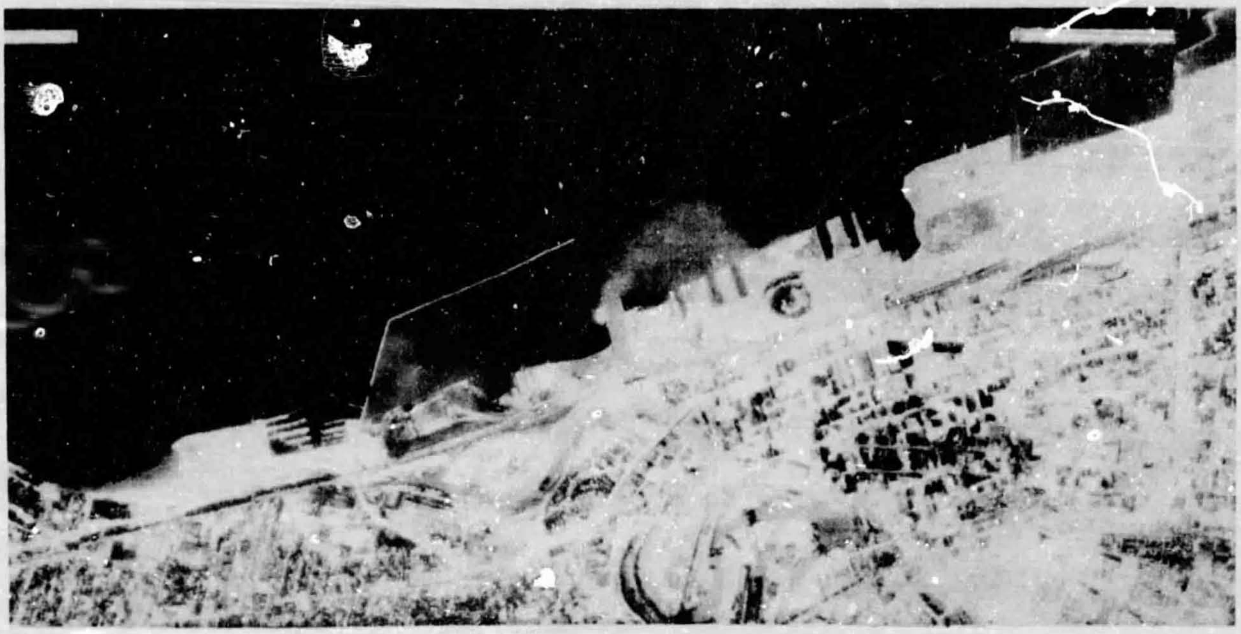
Band 5

E-8550

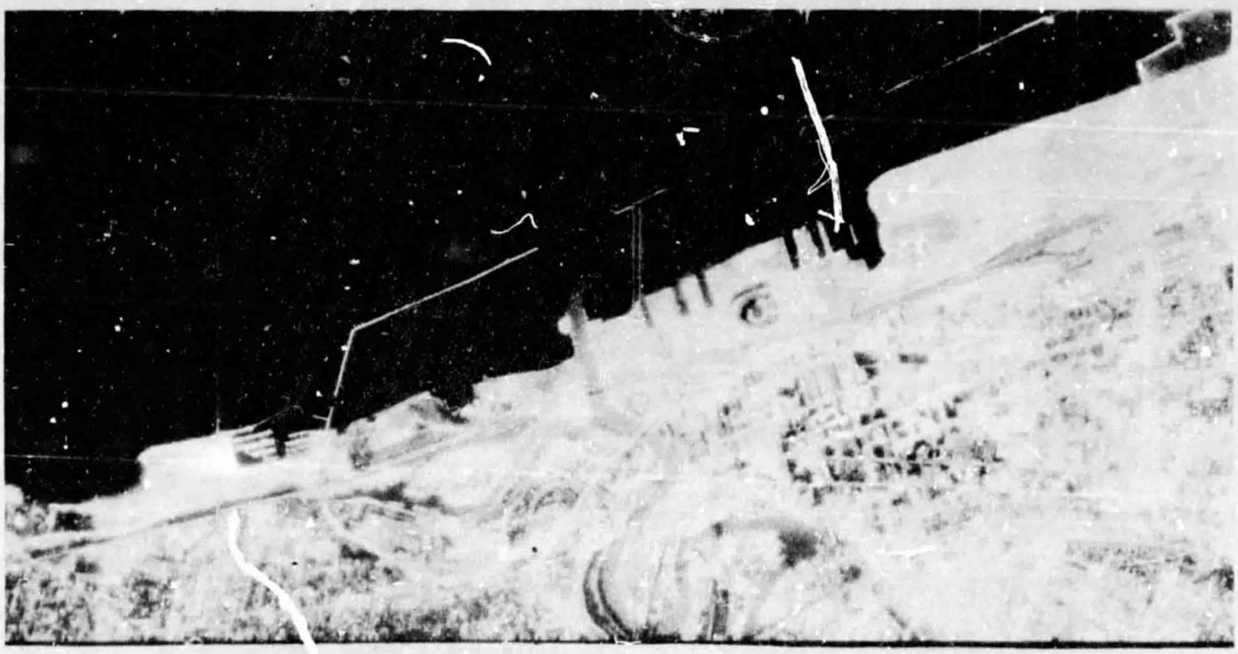


Band 7

Figure 17. - 7/28/75, 11:00 AM



Band 5



Band 7

Figure 18. - 7/28/75, 4:49 PM

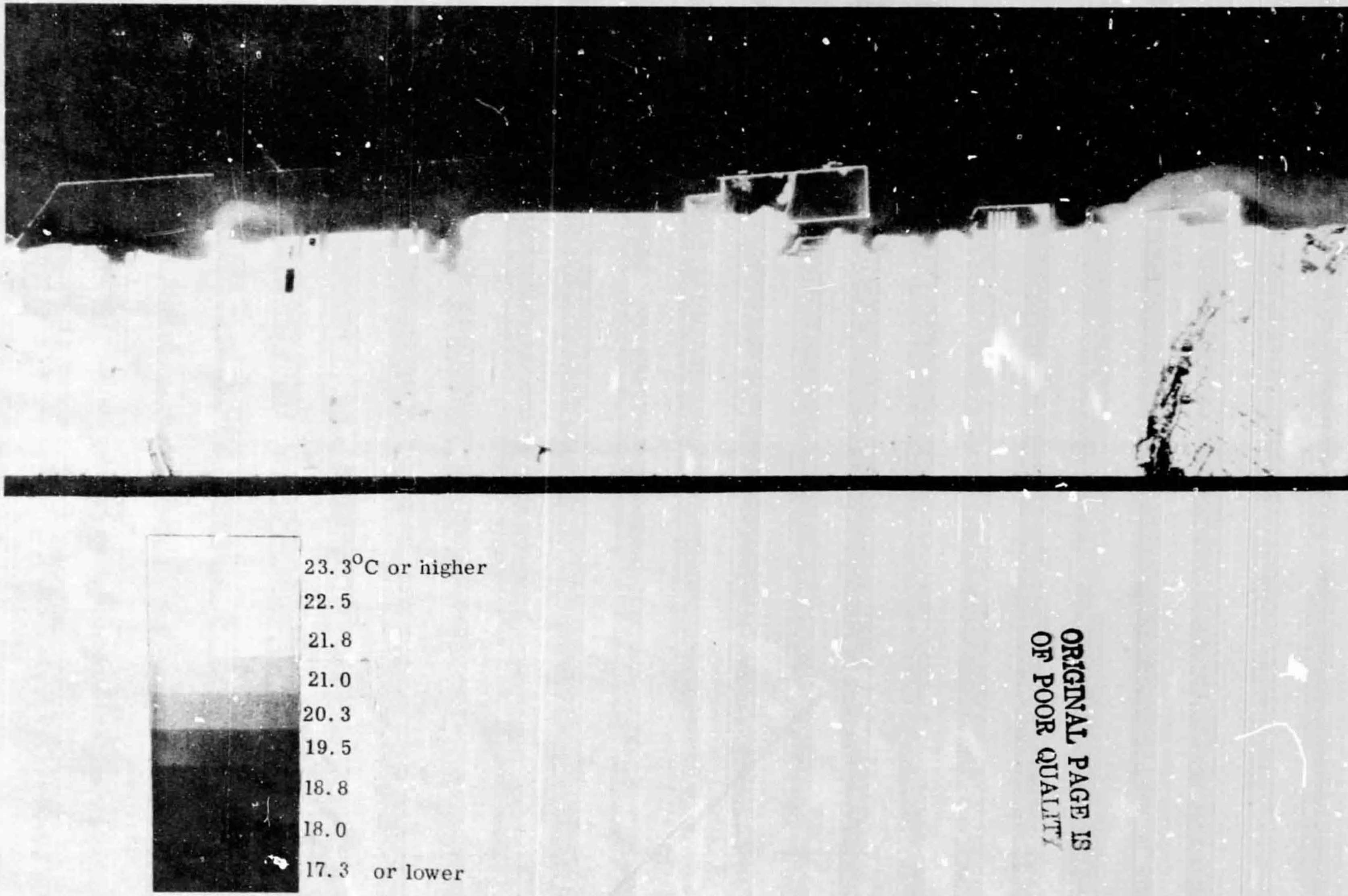
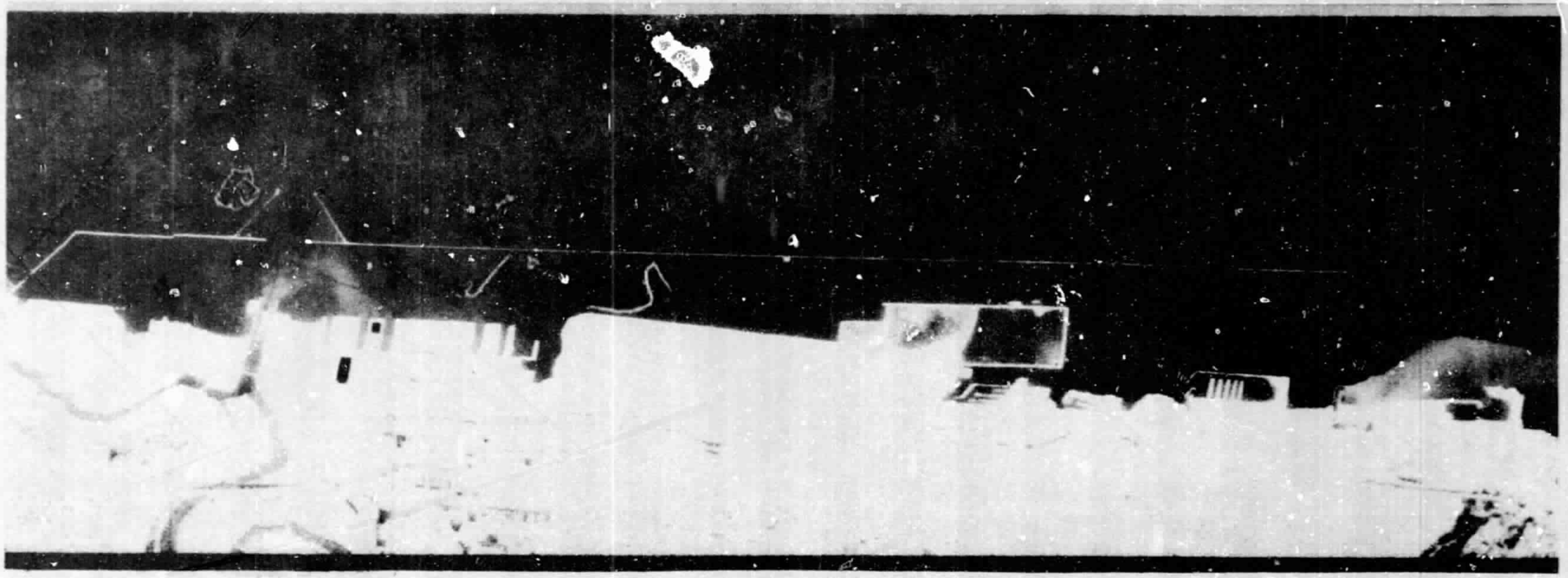


Figure 19. - 7/25/75, 3:35 PM, Thermal Infrared, Band 11



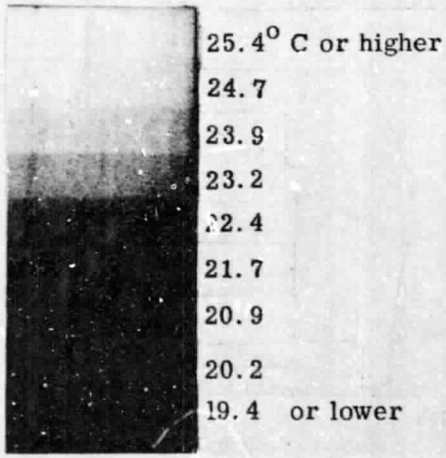


Figure 20. - 7/28/75, 3:22 PM, Thermal Infrared, Band 11

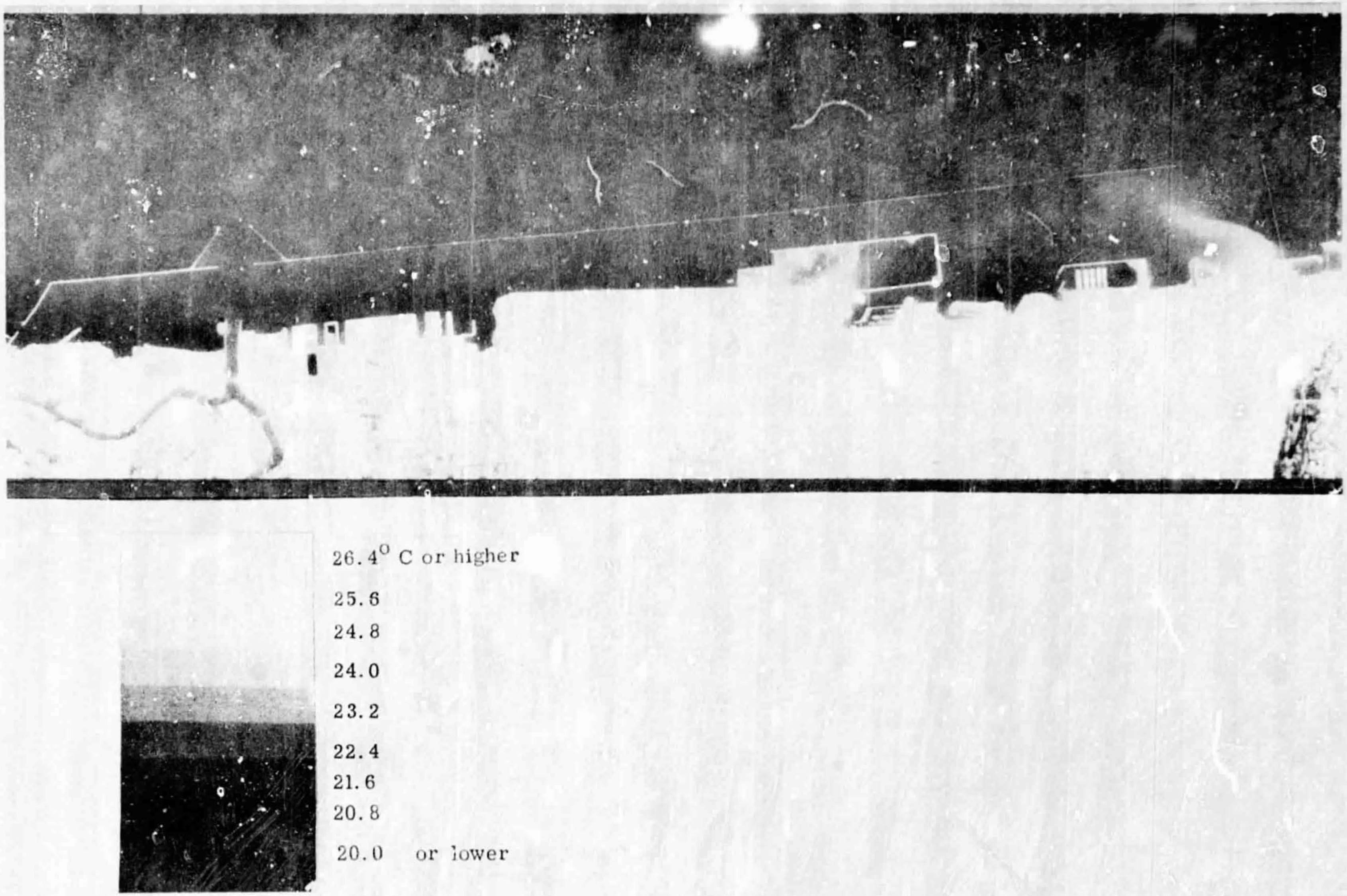


Figure 21. - 7/29/75, 3:30 PM, Thermal Infrared, Band 11